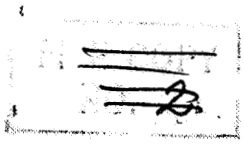

TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 219

CONTROL PROBLEMS ON LARGE AIRPLANES.

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CONTROL PROBLEMS ON LARGE AIRPLANES.*

By Edward P. Warner.

As airplanes continue to increase in size, it becomes progressively more difficult to control their flight by simple manual operation of the usual system of elevator, rudder and ailerons. Designers have so far been able, thanks to a growing knowledge of aerodynamics, to meet the situation by the development of more efficient control surfaces requiring less force to produce a given effect than did the older types, but that cannot continue indefinitely. The time will finally come when it will be necessary either to go over to mechanical or electrical operation of the controls or to abandon the present form of control entirely, replacing it by some device wherein the pilot's force is multiplied and the control is made, to a certain extent, to operate itself, or at least to refrain from offering direct opposition to the pilot's efforts.

In a sense, the ordinary balanced control is in itself such a device, and balanced controls are now fitted on all airplanes of very large size. They consist simply of surfaces which lie partly ahead of and partly behind the hinge, instead of having the hinge at the leading edge. The pressure on the part of the surface forward of the hinge tends to increase any divergence from the neutral position of the controls, and so acts against the force on the

* Taken from Christian Science Monitor.

rear part of the surface. Such balancing would be all-sufficient if the center of pressure of the air reaction on an inclined surface were the same under all conditions, as the hinge could then be set back exactly to the center of pressure, and the only force exerted by the pilot would be that necessary to overcome friction in the system, but unfortunately that is not the case. The center of pressure moves as the angle at which the surface meets the air is changed, and no such thing as perfect balancing is possible, although, as already noted, there has been considerable progress in approaching that ideal in the last few years..

If the ordinary type of balance is deemed insufficient, the next step is to use an assembly of surfaces such that the force on one will help to move some other. The most notable instances of that sort are furnished by the De Havilland aileron gear, the Flettner rudder and the Loening aileron, all of which are of enough interest to receive special mention.

The De Havilland Gear.

Generally speaking, there is an upward pressure on both ailerons of an airplane under conditions of normal flight, and both ailerons would move upward if they were not connected in such a way that one cannot go up unless the other goes down at the same time. The fundamental idea of the De Havilland gear is that the aileron is allowed to move farthest in the direction in which it tends to move in any case, and less far in the direction in which it has to be forcibly pushed. Instead of pulling one aileron up 10 degrees

and the other down by the same amount, the one goes up 15 degrees and the other down five. This differential action somewhat reduces the force required on the control under many conditions, and also improves the effectiveness of the control at very low speeds of flight.

The Flettner Rudder.

From the point of view of reduction of force exerted by the pilot to produce a given effect, the Flettner rudder appears to take high rank in efficiency. Successful practical trial has been given it, both on ships and airplanes. Without going into questions of mechanical detail, it may be said to consist simply of a small auxiliary surface, hinged to the rear of the rudder, elevator or aileron itself. Instead of turning the rudder, the pilot's helm turns only the auxiliary member, and the force on that member then acts to turn the rudder. Being applied far to the rear of the rudder hinge, it is very efficient in that capacity. The necessary force can be very largely reduced, but the information at hand is not sufficient to make it possible to give specific figures as to the effect of the Flettner device on the aileron control, for example, and as to the size of the airplane up to which manual operation of the controls seems likely to prove satisfactory when this auxiliary controlling attachment is used.

Other Possible Methods.

Analysis of the problem reveals several general lines along

which it is possible to proceed in order to reduce the force required on a control. In the first place, the gearing may be changed so that the pilot exerts a small force through a large distance instead of a large force through a small distance. That possibility was discussed in this column last week and was seen to be subject to certain very distinct limitations.

Second, the lever arm of the force on the control surface may be reduced with respect to the hinge by getting the effective center of pressure closer to the hinge line. This is the idea of all balancing devices.

Third, the size of the surface to which the pilot's force is directly applied may be reduced, either by the use of an auxiliary surface, as in the Flettner device, or by the replacement of the ailerons and other controls now commonly used with something entirely new in form and different in operation. Such a fundamental change in control methods must at least be regarded as a possibility. A very ingenious application of the idea of using one surface as an auxiliary to control the motions of another has recently been made by the Loening Company, American builders of airplanes and seaplanes. Mr. Loening has removed the ailerons from their accustomed position at the rear of the wing and placed them at the leading edge, with the object of causing the wing to twist in such a direction as to reinforce the aileron action. When the ordinary type of aileron is pulled down to increase the lift on that side of the airplane it produces an upward load on the rear spar of the wing. That spar then bends upward, warping the wing and decreasing

the lift in that particular neighborhood. The distortion of the wing itself thus acts directly against the intended effect of the aileron. With front-edge ailerons, the wing warps in the opposite sense, as the front spar bends upward instead of the rear, and the aileron is aided by the wing without exacting any extra effort from the pilot. The front-edge aileron in itself, neglecting any effects of wing warping, is somewhat less effective than one placed at the trailing edge, but the overall efficiency of the system is improved by the change in those airplanes where the wing structure is such that the wing is relatively flexible and warps readily. That is particularly likely to be the case in monoplanes.

The fourth and last of the possible avenues of approach to a reduced controlling force is through a change in the direction of application of that force. If a heavy weight is resting on ice, pulled downward by gravity, a force equal to the pull of gravity itself will be required to lift it into the air. Very little force, however, need be exerted to slide the weight along the ice. Similarly, it is possible that we shall see the development of types of control in which the force is very small because the movement is at right angles to the principal load on the control member. There have already been trials of such devices, but they have failed because of mechanical complexity or because they gave an insufficiency of maximum controlling power. One example is the use of sliding wing-ends for lateral control, a movable portion of one wing-tip being slid outward or inward in a horizontal plane, so increasing

the lifting area on one side of the center line of the airplane and giving an unsymmetrical distribution of the lift itself. Since the force on the moving surface is vertical and its movement horizontal the pilot needs only to overcome friction. That particular mechanism is not powerful enough to replace ailerons, but it contains a very interesting idea, and it is quite possible that satisfactorily effective mechanism may be developed along the same general line. If so, trouble with excessive controlling forces should be disposed of once and for all.

Behind all these suggested schemes lies the possibility of the servo-motor, of mechanical or electrical operation, but that should be put off as long as possible. It is the duty of the engineer to spare no effort to improve the control system itself so that the introduction of a brand-new mechanical element, with its necessary increase of complication, may be avoided.